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The age of sexual maturity in Japanese giant flying squirrels, *Petaurista leucogenys*

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Abstract. I determined the age of sexual maturity in Japanese giant flying squirrels, *Petaurista leucogenys*. The degree of testicular development was estimated in 25 males 224 times during eight years. The scrotum began to extend at the age of 7.5-8.5 months, and was slightly swollen in males 8-13 months old. Testes of 1/2-3/4 size were observed in males from 14 months onward. By the mating season when they were 21-22 months old, the proportion with full-sized testes was 57% of the males. All five males of 27-28 months of age had full-sized testes. One 22 month-old male and one 27 month-old were observed copulating. Summer-born males had slightly faster developing testes than spring-born males. None of 19 young females were observed in estrus. The attainment of sexual maturity in males at 21-22 months of age seems very late as the intermediate-sized rodents. It is suggested that mothers allow their young to remain with them for 1-1.5 years until they become sexually mature in order to increase the survival rate of their young, thereby compensating for their small litter sizes of one or two.

Key words: flying squirrels, *Petaurista leucogenys*, scrotum, sexual maturity, testis.

Rodents achieve sexual maturity at a great range of ages, depending on the species. In general, sexual maturity is reached later in larger rodents than in smaller rodent species. Beavers, *Castor canadensis*, and marmots, *Marmota monax*, for example, which exceed 5 kg in body mass, do not become sexually mature until they are two years old, whereas small voles and mice weighing less than 100 g mature very early; *Microtus pennsylvanicus*, for example, becomes sexually mature after 25-45 days (Bourlière 1964, Eisenberg 1981). Adult Japanese giant flying squirrels, *Petaurista leucogenys*, attain weights of up to 1.3 kg (Kawamichi 1996), and are therefore presumed to become sexually mature relatively late.

Various aspects of the ecology of the essentially nocturnal Japanese giant flying squirrel have been investigated. These include: food habits (Ando *et al*. 1985a, Kawamichi 1997); feeding behavior (Ando *et al*. 1984, 1985b, Funakoshi and Shiraishi 1985), and activity rhythms (Baba *et al*. 1982). No information has previously been available, however, on the age of sexual maturity in

either captive or wild populations.

The purpose of this paper, therefore, is to describe for the first time the age of sexual maturity in wild Japanese giant flying squirrels, and to discuss the factors affecting the age of sexual maturity in this species.

Materials and Methods

The study area consisted of 0.65 km² (65 ha) of mixed deciduous and coniferous temperate forest situated adjacent to Nara City, central Japan (34° 41′N, 135°50′E ; elevation 98–150 m), (see Kawamichi 1997). The climate of the study area is relatively mild, with snow falling occasionally in winter, but with snow-cover not lasting more than a few days. Research into the ecology and behavior of *P. leucogenys* was conducted at this site for eight years, from April 1983 to January 1991. A total of 977 nights were spent in the field, spread throughout each year.

I located giant flying squirrels at night, using a 9-volt searchlight, while walking at random through the study area. All resident squirrels were identified by a combination of scars on their ears and details of their pelage with 8–16× Nikon zoom binoculars. Very young individuals show few clearly recognizable individual characteristics, however their identification was aided by the fact that they move in close association with their mothers.

Exact dates of birth could not be determined for most individuals in the study area, so all birth dates were calculated by the addition of the mean gestation period (74 days) to the middle dates of the biannual mating seasons, those being 1 March for the spring-born litter, and 15 August for the summer-born litter. The degree of error between calculated and real birth dates, was considered to be within one month for spring-born litters, and within two weeks for summer-born litters, because the winter mating season covered approximately two months, whereas the May–June mating season lasted one month.

When immature males were encountered, the developmental stage of their testes was assessed as belonging to one of five categories : full size, 3/4–1/2 size, at an early stage of development, the extension of a space for the scrotum, and undeveloped (Fig. 1). After sexually maturity, the size of the testes of adult males were estimated, illustrated, and classified into four categories : full size, 2/3–3/4 size, 1/3–1/2 size, and completely regressed. The size of the vulvae of individually identified females was also described and illustrated.

Mating behavior was observed during 16 mating seasons during the eight-year study period, and observations were made on most nights during each mating season. Females in estrus were recognized by their swollen, pink vulvae, and by the behavior of males. When females came into estrus, aggressive behavior among males congregating at their nests was observed. I followed estrous females after they left their nests in order to confirm mating. Mating behavior and the identities of mating males were all recorded.

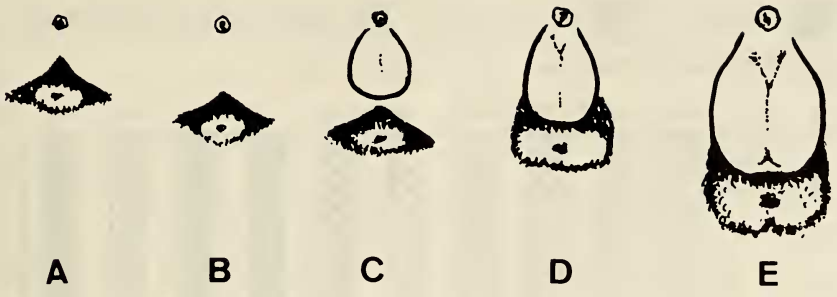

Fig. 1. Five categories of testicular development. A: Undeveloped; B: Extension of a space for the scrotum; C: Early development of testes; D: 2/3 size testes; E: Full size testes. The anus is shown under grayish pelage.

Results

The Japanese giant flying squirrel has two mating seasons, the first from mid-November to mid-January, and the second from mid-May to mid-June (Kawamichi *et al.* 1987). Gestation lasts 74 days (Kawamichi unpubl.), and the addition of this period to these two mating seasons each year indicates that the two birth seasons occur mainly from early February to early April, and then from late July to late August.

Litters of one or two altricial young are born in tree cavities. They begin to appear at their nest entrance approximately 45 days after birth, and leave their nests when 59 or more days old (Kawamichi unpubl.). The individuals examined for this study were those which were observed for six or more months after first appearing outside their nests. These included 25 males (born from 17 mothers) and 19 females (from 12 mothers), which were observed for between six months and 5.5 years.

1. Development of testes

For 25 different males aged 2-28 months, the degree of external testicular development was estimated, and the size of the scrotum was recorded repeatedly, a total of 224 times. Testis condition of a total of 93 males was determined bimonthly except for males aged 2-8 months (see Fig. 2).

The first indication of sexual development in males was the extension of a very narrow space for the scrotum between 6.5-7 months of age. The scrotum began to extend at the age of 7.5-8.5 months (Fig. 1), and was slightly swollen in males 8-13 months old. A male of this age, which met an accidental death, had testes of about 1 cm in diameter. From the age of nine months, small rounded testes, in the early stages of development, were visible in the scrotum. Testes of 1/2-3/4 size were observed in males from 14 months onward, and the proportion of individuals with testes of this size increased steadily until 18 months of age (Fig. 2).

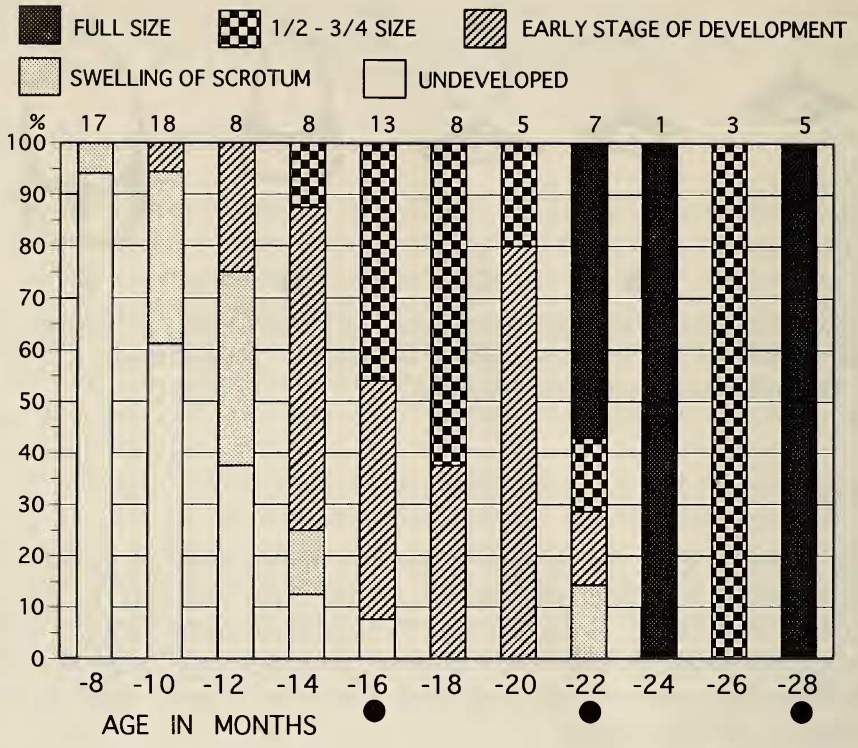

Fig. 2. Age-related development of testes. Bimonthly changes in the proportion of males with testes of various sizes. Upper figures refer to the number of males. Solid circles indicate the mating season.

Regardless of whether they were spring- or summer-born, the first opportunity to participate in a mating season came when males were 15-16 months old. At this stage, young males were fairly evenly divided between those with testes in early stages of development, or between 1/2 and 3/4 size (Fig. 2). By their second mating season, they were 21-22 months old, and the proportion with full-sized testes was 57.1%. By their third mating season, all five identifiable males of 27-28 months of age had full-sized testes.

Males which were between 15 and 17 months old were not observed mating during their first mating season, and only one 22 month-old male during its second mating season, and one 27 month-old during its third mating season were observed copulating. It is assumed, therefore, that males may become sexually mature from the age of 21-22 months.

Summer-born males had slightly faster developing testes than spring-born males (Table 1). By 9-10 months of age, spring-born males still had undeveloped testes, whereas more than half of the summer-born males of the same age had already developed a space for the scrotum ; the difference in the proportion of males with undeveloped testes was significant (Fisher's exact probability test, $p=0.02$). During the first mating season, the difference in the degree of

Table 1. The difference in testis development between spring-born and summer-born males. Figures represent the number of males. Capital letters are the initials of months ; bimonthly periods begin from 1st of each month for spring-born males and from 15th for summer-born males.

	Age in months										
	0-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28
Spring-born males											
	M-O	N-D	J-F	M-A	M-J	J-A	S-O	N-D	J-F	M-A	M-J
Full size	0	0	0	0	0	0	0	2	0	0	2
1/2-3/4 size	0	0	0	0	0	1	0	0	0	1	0
Early stage	0	0	0	2	4	1	1	1	0	0	0
Swelling scrotum	0	0	1	1	0	0	0	0	0	0	0
Undeveloped	6	7	3	1	1	0	0	0	0	0	0
Summer-born males											
	A-A	M-J	J-A	S-O	N-D	J-F	M-A	M-J	J-A	S-O	N-D
Full size	0	0	0	0	0	0	0	2	1	0	3
1/2-3/4 size	0	0	0	1	6	4	1	1	0	2	0
Early stage	0	1	2	3	2	2	3	0	0	0	0
Swelling scrotum	1	6	2	0	0	0	0	1	0	0	0
Undeveloped	10	4	0	0	0	0	0	0	0	0	0
Overal	17	18	8	8	13	8	5	7	1	3	5

development was also significant (Fisher's test, $p=0.05$; using data from 15-16 month old spring-born males, and from 15-18 month old summer-born males).

The rate of development of testes varied individually. The testes of three of the 25 males observed developed very slowly ; one retained a narrow space for the scrotum for 15 months, and two still had small testes when 18 and 22 months old, respectively.

Adult male Japanese giant flying squirrels experience regular regression and recrudescence of their testes, with regression occurring annually during the non-mating season in July and August (Kawamichi unpubl.). The period of testicular regression occurs first for summer-born males when 11-12 months old ($n=4$), and for spring-born males when they are 17-18 months old ($n=2$). The testes of all six males were, however, continuously developing. During the second period of regression, one summer-born male 23-24 months old retained full-sized testes, while the testes of one 32 month old spring-born male regressed and redeveloped during summer.

The proportion of adult males with full-sized testes decreased during the second half of February and the first half of March (Kawamichi unpubl.). A similar decrease in testis size was also found in three out of four 19-20 month old summer-born males (see the increased proportion of small testes in Fig. 2). The testes of one 19 month old male, however, regressed from March through the May-June mating season.

2. Sexual maturity in females

Among immature females, the size of the external vulvae increased very

slowly until their first estrus. None of 19 young females were observed in estrus during the mating season. The vulvae of five, out of the 19 females observed, were examined closely during the mating season when they were 9–10 months old. Only one of the five had slightly swollen vulvae. Another female had a similarly swollen vulva when it was 16 months old.

Young females usually dispersed from their natal territories before their first estrus (Kawamichi unpubl.), thus it was difficult into observe the age of sexual maturity. Furthermore, because of the short period of estrus, the occurrence of estrus during a particular mating season was very difficult to recognize. The data indicate, however, that young females do not come into estrus during the mating season that takes place when they are 9–10 months old.

Discussion

It appears that there are three possible factors affecting the age of sexual maturity in Japanese giant flying squirrels that should be considered. The first factor is the interval between the two annual mating seasons; the second factor is the slightly different age of sexual maturity between spring- and summer-born males; and the third factor is social.

In seasonally breeding mammals, the timing of sexual maturity is related to the interval between mating seasons. In species such as the Siberian chipmunk, *Tamias sibiricus*, which has one short mating season each year (Kawamichi and Kawamichi 1993), mating occurs at the age of 11 months, despite their small body size. In Japanese giant flying squirrels, which have two mating seasons each year, the first mating season occurs when they are 3.5 months old, and later every six months (9.5, 15.5, 21.5, and 27.5 months). Therefore, the interval between mating seasons would, at most, postpone their sexual maturity six months.

Summer-born males reach sexual maturity slightly sooner than spring-born males. One possible reason for this is that food availability and the nutritional value of available food differ for summer- and spring-born males. Young spring-born litters begin foraging from late April onward, when their diet consists largely of leaves and buds, whereas summer-born litters begin foraging from mid-October onward when their diet consists largely of seeds (Kawamichi unpubl., Kawamichi 1997). Further study is required to establish whether this dietary difference influences the growth rate of young squirrels after weaning and therefore influences the age of sexual maturity.

Given that sexual maturity in extra-large rodents, such as beavers and marmots, occurs at two years of age (Bourlière 1956, Eisenberg 1981), the attainment of sexual maturity at 21–22 months of age in Japanese giant flying squirrels seems very late given its intermediate size. Their relatively late maturation should be considered, however, from the perspective of reproductive success. Japanese giant flying squirrels have small litters of just one or two young (Kawamichi 1996), thus the maximum number of young they can raise each year is four. Young squirrels of both sexes remain in their natal

territories for 1-1.5 years, until they are sexually mature (Kawamichi unpubl.). These facts suggest that mothers allow their young to remain with them until they become sexually mature in order to increase the survival rate of their young, thereby compensating for their small litter sizes. Furthermore, young squirrels may delay reaching sexual maturity so as to have longer to grow up in their mothers' territories.

The age of reaching sexual maturity in Japanese giant flying squirrels is likely to be determined by three inter-related factors, the growth rate of the young, their longevity, and life time reproductive success.

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